Effects of Thiamin Supplementation on Performance and Health of Growing Steers Consuming High Sulfate Water

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Summary

Thiamin injections are often used to treat sulfate induced polioencephalomalacia (PEM) in beef cattle. It is unclear whether supplemental thiamin will reduce the incidence of PEM and improve performance in steers consuming water with elevated sulfate levels. This study was conducted to determine the effects of thiamin supplementation on performance and health of growing steers consuming water with high sulfate levels. Sixty-three steers (737 ± 2.97 lb) were stratified by weight and randomly allotted to one of nine pens. Pens were assigned to one of three treatments (3 pens/treatment) based on water sulfates and thiamin supplementation. Treatments were: 1) low sulfate water (average = 393 ppm sulfates) with no supplemental thiamin (LS); 2) high sulfate water (average = 3786 ppm sulfates) with no supplemental thiamin (HS); and 3) high sulfate water (average = 3790 ppm sulfates) with supplemental thiamin at 1 g/hd/d (HST). The study was conducted from June 16 to August 22, 2003. Water was obtained from a rural water system and sodium sulfate was mixed in the water to create desired sulfate levels in the HS and HST treatments. Steers were fed a diet containing grass hay, wheat middlings, and supplement. The supplement was identical for all treatments except for the addition of thiamin to HST. Water intake did not differ between treatments (P = 0.24). Steers on HST had a higher (P = 0.05) ADG than those on HS, and steers on LS had a higher (P = 0.01) ADG than HS or HST (1.79, 1.08, 1.39 lb/d for LS, HS, and HST, respectively). Steers on LS had higher (P = 0.01) DMI than steers in HS or HST. Steers on LS and HST had a higher (P < 0.10) gain/feed than steers on HS (0.192, 0.141, and 0.172 for LS, HS, and HST, respectively). The incidence of PEM was 4.8 and 14.3% for HST and HS, respectively, compared to no cases of PEM in the LS treatment (P < 0.10). There were no differences in the incidence of PEM between HST and HS (P = 0.29). Thiamin supplementation (1 g/hd/d) improved ADG and gain/feed in steers receiving high sulfate water.

Introduction

Water in South Dakota is often high in sulfates (APHIS, 2000). Gould et al. (2002), accounting for the sulfur contribution of both water and feed, found diets of cattle in South Dakota and the surrounding region commonly have sulfur levels above recommended levels (NRC, 1996). High dietary sulfur levels have been associated with polioencephalomalacia (**PEM**; McAllister et al. 1997), a neurological disorder that causes incoordination, blindness, anorexia, depression, seizures, and possibly death. Data from our laboratory showed that increased levels of sulfates in the water supplied to growing steers decreased performance and increased the incidence of PEM (Patterson et al. 2002, 2003).

Thiamin injections are often recommended as therapeutic treatment for diagnosed cases of PEM. A thiamin deficiency has been associated with PEM (McDowell, 1989) due to an antagonism between the ingested sulfur and thiamin in the rumen (Brent and Bartley, 1984). Recent evidence has shown PEM to be associated with hydrogen sulfide production in the rumen, and not with blood thiamin levels (McAllister et al. 1997; Loneragan et al. 1998). Data are lacking to show the effects of supplemental thiamin to cattle receiving water with elevated sulfate levels. The objective of this study was to evaluate the effects of supplemental thiamin on the performance and health of growing steers consuming water with high sulfate levels during the hot summer months.

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Materials and Methods

The study was conducted from June 16 to August 22, 2003, at South Dakota State University's Cottonwood Range and Livestock Research Station, near Phillip, SD. Sixty-three crossbred steers (737 ± 2.97 lb) were stratified by weight and randomly assigned to one of nine pens (7 steers/pen). The pens were randomly assigned to one of three treatments based on water sulfates and thiamin supplementation. Treatments were 1) low sulfate water with no supplemental thiamin (**LS**), 2) high sulfate water with no supplemental thiamin (**HS**), and 3) high sulfate water with supplemental thiamin at 1 g/hd/d (**HST**).

The LS water was from a rural water system, and the HS and HST treatments were created by adding sodium sulfate to the LS water to a targeted 4000 ppm sulfates (Table 1). Water samples were taken daily and composited by week. Weekly composites were analyzed for sulfates by the SDSU Water Resource Institute, Brookings, SD (Table 1).

Steers were housed in dry-lot pens and fed grass hay and wheat middlings (diet consisted of 55% hay and 45% wheat middlings; 13.16% CP, 0.41 Mcal/lb NEg, 0.95% Ca, 0.58% P; DM basis). Supplements (Table 2) were top dressed at a rate of 1 lb/head/day. The HST supplement had thiamin mononitrate included at 1 g/lb. Rations were fed in concrete bunks at 0800 daily. Bunks were managed to be clean just prior to feeding, and any orts were weighed and recorded daily. Free choice salt was fed ad-libitum to all treatments in covered mineral feeders. Water was supplied in oval aluminum tanks (150 gallons). Water consumption was measured by the daily change in water depth and adjusted for evaporation and precipitation. Evaporation and precipitation data were obtained from a weather station located adjacent to the research feedlot). Animal health was monitored daily. Cattle were diagnosed with PEM when showing multiple clinical symptoms characterizing the disease. Symptoms included depression, blindness, incoordination, star gazing, anorexia, and seizures. Necropsies were performed on all mortalities, and tissue samples were submitted to the South Dakota State University Diagnostic Laboratory for disease confirmation.

Steer weights were taken in the morning on two consecutive days at the beginning and end of the experiment. Access to water was denied 12 h prior to body weight measurements. At the end of the experiment all pens were placed on rural water (LS treatment) and limit fed (approximately 2% of BW, DM Basis) for 5 d prior to final weight measurements. ADG was calculated for each experimental unit (pen) with data from dead cattle removed. Gain efficiency was calculated as ADG divided by average daily DMI.

The effects of treatment on body weight, ADG, DMI, gain/feed, and water intake were analyzed by ANOVA using PROC GLM of SAS (SAS Inst. Inc., Cary, NC) with pen being the experimental unit. Morbidity and mortality were analyzed with Chi-Square analysis in PROC FREQ of SAS.

Results and Discussion

The daily maximum temperature recorded during the study period was 111°F, with a mean maximum of 92°F. Steer weights at the end of the experiment (Table 3) were different between all treatments ($P < 0.10$), with the LS steers the heaviest and HS steers the lightest. Thiamin supplementation (HST) improved ADG by 29% over the HS treatment ($P < 0.05$), but was 22% lower ($P < 0.05$) than the LS treatment (Table 3). Dry matter intake (Table 3) in the HST and HS treatments was 13.2% and 18.4% less, respectively, than LS treatment ($P < 0.05$). DMI did not differ ($P = 0.22$) between HST and HS. Gain efficiency (Table 3) was greater ($P < 0.10$) for the LS and HST treatments compared to the HS treatment ($P < 0.10$). Water intake did not differ between treatments ($P = 0.24$).

Patterson et al. (2002) reported a 27% reduction in ADG of steers receiving water with 3100-3900 ppm sulfates over steers on a 400 ppm sulfate treatment, compared to a 45% and 23% reduction for HS and HST in this experiment, respectively. Patterson et al. (2002, 2003) also showed a decrease in water intake, DMI, and gain/feed when comparing treatments above 3000 ppm to the 400 ppm sulfate treatment. Unlike Weeth and Hunter (1971) and Patterson et al. (2002, 2003), this study showed no difference in water intake between sulfate levels.

There was no incidence of morbidity or mortality in the LS treatment, but calves on the HS treatment had a 14.3% (3/21) and 9.5% (2/21) morbidity and mortality rate, respectively (morbidity difference between LS and HS, $P < 0.10$). The steers on HST treatment had a 4.8% (1/21) incidence of morbidity and mortality, which was not different than either the HS or LS treatments ($P > 0.50$). All calves that were morbid were pulled out of their home pen for showing the symptoms of PEM. There were no differences in mortality between treatments ($P >$ 0.50). Out of the two calves that died in the HS treatment, one was confirmed PEM by diagnostic analysis of brain tissue. The remaining animal showed signs of PEM prior to death, but PEM was not confirmed due to autolysis of the tissue. The single mortality in the HST treatment resulted in an inconclusive diagnosis as well. This steer was not observed showing signs of PEM prior to death. We have observed cases in the past where sudden death occurred and diagnostics did confirm PEM, but a diagnosis was not made in this mortality. Patterson et al. (2002, 2003) showed a difference in the incidence of PEM and mortality when comparing steers on water with low sulfate levels versus those receiving water with high sulfate levels.

High daily sulfur intakes were likely associated with the onset of PEM. The HS and HST steers had dietary sulfur levels of 0.85% and 0.88%, respectively, compared to a dietary sulfur level of 0.25% in the LS treatment. Loneragan et al. (1998) found that a dietary sulfur level of 0.90% from feed was associated with PEM. Patterson et al. (2002) found that 0.70% dietary sulfur was associated with PEM. The NRC (1996) gives a maximum tolerable dietary sulfur level of 0.40%, and a requirement of 0.15%. Diets with sulfur levels above 0.20% have shown to impair digestion in the rumen of finishing steers (Zinn et al., 1997).

Thiamin deficiency is a potential cause of PEM (McDowell, 1992). McAllister et al. (1997) and Loneragan et al. (1998) found that PEM was associated with hydrogen production in the rumen, however, and not with blood thiamin levels. The active form of thiamin may not be impacted by hydrogen sulfide production (Loneragan et al., 1997). Hydrogen sulfide is a toxic gas that can be inhaled following eructation from rumen (Kandylis, 1984). The inhaled hydrogen sulfide disrupts energy metabolism in brain cells and causes necrotic lesions which characterize PEM. We evaluated our data with all cattle diagnosed with PEM removed (data not shown), and found the same statistical differences between treatments in ADG and feed efficiency. The fact that thiamin supplementation improved performance independent of clinical PEM could be due to thiamin having an effect on sub-clinical PEM, or supplemental thiamin could have voided a deficiency.

Thiamin supplementation to cattle on high sulfate water improved ADG and feed efficiency.

Implications

Water high in sulfates decreased weight gains and feed efficiency in steers fed a growing ration. Sulfates in the water were associated with polioencephalomalacia. Thiamin added to the daily diet improved gain in steers on high sulfate water. More research is needed to examine the effects of thiamin levels in the diet on performance and health of cattle on high sulfate water.

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Tables

Table 1. Sulfate levels in water supply for growing steers in western South Dakota in 2003

Water Analysis	Low Sulfate (LS)	High Sulfate (HS)	High Sulfate with Thiamin (HST)
Projected, ppm	400	4000	4000
Average, ppm	393	3786	3790
Range, ppm	372 – 416	2188 - 4081	2188 – 4081

Table 2. The nutrient composition of supplements fed to growing steers receiving various sulfate levels in the water supply[a]

Item	LS and HS Supplement	HST Supplement
Ca, %	11	11
Mn, ppm	50.0	50.0
Zn, ppm	100.0	100.0
Cu, ppm	150.0	150.0
Co, ppm	1.5	1.5
Se, ppm	0.5	0.5
I, ppm	5.0	5.0
Vit. A (added), IU/lb	45,000	45,000
Vit. D (added), IU/lb	4,500	4,500
Vit. E (added), IU/lb	60	60
Thiamin (active), g/lb	NA	1.0

[a] As-fed basis.

Table 3. Intake and performance of growing steers supplied water with various sulfate levels and thiamin supplement in 2003

Item	Low Sulfate (LS)	High Sulfate (HS)	High Sulfate with Thiamin (HST)	SEM
Observations	3	3	3	
Initial wt, lb	736	732	744	2.97
Final wt, lb	856[a]	803[b]	836[c]	5.69
ADG, lb/d	1.78[d]	1.07[e]	1.38[f]	0.09
Dry matter intake, lb/d	20.50[d]	16.71[e]	17.78[e]	0.56
Gain/Feed	0.192[a]	0.143[b]	0.172[a]	0.009
Water intake, gallons/d	11.90	10.78	11.46	0.42

[a,b,c] Within a row, means without a common superscript letter differ ($P < 0.10$).
[d,e,f] Within a row, means without a common superscript letter differ ($P \leq 0.05$).